FERMENTATION BYPRODUCT FEED FORMULATION AND PROCESSING

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] This invention concerns the formulation and processing of fermentation byproducts into useful feed products.

2. Description of Related Art

[0002] In the animal agricultural industry, a great deal of effort has been placed into providing nutritional high quality feed materials. Fermentation byproducts have been fed to domestic animals for hundreds of years in both in wet and dried form. Fermentation processes tend to concentrate nutrients in the by-products, such as, for example, corn, wheat, and/or barley, by using up the fermentable carbohydrates. Some vitamins and other nutrients are increased by the (yeast) fermentation process. For example, corn, which contains about 8% crude protein, is increased to a protein level of about 22% to 28%, on a 12% to 13% moisture level. Fat and fiber in spent corn are also typically increased to at least double their original levels through concentration.

[0003] Corn is a good candidate for fermentation due to its relatively high carbohydrate content. However, the low protein content of the grain in general, and its low content of the amino acid lysine, leads to low levels of these nutrients in the spent grain.

[0004] The spent grain has traditionally been sold to the animal feed industry as a product known as "distillers dried grain w/sol(DDGS)", "distillers dried grains (DDG)," and "wet distillers grains (WDG)," or "wet brewers grain (WBG)," and "dried brewers grain (DBG)." With much of the carbohydrate used up in the fermentation process and the relatively low levels of protein and energy, fermented grain has been of little interest to the poultry and swine industries. As a result, the majority of the fermentation byproducts from distillers and brewers, e.g., fermented grains, have been used as feeds for ruminants, including dairy cows.

[0005] In today's modern dairy operations ruminant animal rations are formulated with different ingredients to provide precise levels of degradable protein to the ruminant animal rumen bacteria and rumen undegradable protein (RUP) (also referred to as UIP or undegradable intake protein) in the ruminant animals' lower gastrointestinal tracts. Animal rations are also balanced to provide known levels of specific amino acids to the animals' lower gastrointestinal tracts.

SUMMARY OF THE INVENTION

[0006] The systems and methods according to this invention use grain fermentation byproducts in general and, in one exemplary embodiment, distilling industry byproducts, as base ingredients in the production of an animal feed or an animal feed supplement to improve the value of the distillers, fermenters and brewers by-products.

[0007] The systems and methods according to this invention allow a user, such as, for example, a brewer, fermenter and/or distiller, to use existing equipment with very little additional capital investment and achieve a high nutrient value ruminant animal feed and/or feed supplement compatible with today's sophisticated ration balancing programs.

[0008] The systems and methods according to this invention permit a user to realize improved drying efficiency of by-products by the use of other grain, grain byproduct or nutrient additives that have a lower moisture level than the wet distillers and/or brewers byproducts and can absorb moisture so that less moisture needs to be removed to achieve an end product with a moisture level of, for example, from about 0% to about 14%.

[0009] The systems and methods of this invention dry the resultant product/mixture at a dryer temperature of from between about 200°F to about 1000°F until the moisture level in the mixture is between about 0% to 14% by weight, and the temperature of the mixture at the end of drying is between about 180°F to about 250°F.

[0010] The systems and methods of this invention cool the resultant product/mixture, including, for example, by ambient air cooling, to a temperature of about 200°F or below, if desired.

[0011] The systems and methods according to this invention allow any brewer, distiller or fermenter to increase the nutrient value of their byproducts in a predictable manner.

[0012] In one exemplary embodiment of the systems and methods of this invention, a user can increase the nutrient value of byproducts by injecting specific nutrient sources into the wet end of the processes and after fermentation and/or distillation procedures.

[0013] The systems and methods according to this invention permit users to produce a large variety of nutritional supplements depending on the purchaser's specifications. Sophisticated nutritional and economic demands of the animal agricultural industry are achieved in a predictable manner using the systems, methods and resultant products according to this invention.

[0014] According to the systems and methods of this invention, the specific nutrient sources injected into/added to the wet end of the process can be used to determine to which animal species the upgraded product will be fed.

[0015] The nutritionally enhanced mixture produced according to the systems, methods and resultant products according to this invention may be fed wet or dry to animals. The form that the product takes for feeding can vary depending on the target animal species, nutrient specifications desired, nutrient density and the shipping distances involved.

[0016] The systems and methods according to this invention alter configuration of proteins in the mixture of wet distillers, brewers or fermenters grains and added nutrients using heat from drying and/or extruding the mixture, including mixtures usable as protein supplements produced for ruminant feeds including the dairy and/or beef industries. The heating which affects the RUP/ UIP, where UIP is used to represent undegraded intake protein, and RUP is used to represent rumen undegraded protein, is performed after the nutrients are added to the wet distiller's, brewers or fermenters grains and/or during mixing of the wet distiller's grains, brewer's grains, fermenter's grains, with nutrients.

[0017] In various exemplary embodiments, the systems and methods according to this invention use equipment such as dryers and extruders that are already in place and conventionally used to produce the non-nutritionally enhanced fermentation byproducts.

[0018] In various exemplary embodiments, the systems and methods according to this invention mix nutrients with distillers, brewers or fermenters byproducts prior to final processing of those byproducts.

[0019] In various exemplary embodiments, the systems and methods according to this invention produce a nutritionally enhanced distiller's, brewer's or fermenter's grain byproduct that may be used by feed managers to produce a complete feed.

[0020] Certain exemplary embodiments of the systems and methods according to this invention also add minerals, energy sources, other protein, vitamins and other nutrients to feed materials to meet customer demands.

[0021] The systems and methods according to this invention permit a distiller, brewer or fermenter for example, to predict, and achieve predicted, nutrient values of a dried end product, including a particular bypass protein (RUP/UIP) level and amino acid content.

[0022] The systems and methods according to this invention permit a distiller, brewer or fermenter for example, to predict the digestible bypass protein (RUP/UIP) and digestible amino acids delivered to a ruminant's lower gastrointestinal tract, and the nutrient

values of a dried end product, including a particular bypass protein (RUP/UIP) level and amino acid content.

[0023] The systems and methods according to this invention alter the drying time and/or amount of heat applied to mixtures of wet distiller's, brewer's or fermenter's grain byproducts and nutrients in terms of time of the byproducts and nutrients exposed to heat and maximum temperatures, which are within predetermined amounts, to predictably control, and achieve a desired, RUP/UIP protein content of the nutritionally enhanced byproducts.

[0024] The methods according to this invention will produce an improved distillers, brewers or fermenters grain by-product by establishing desired nutritional values for the product to be produced, including a desired ruminant animal bypass protein range and amino acid levels. The enhanced product is produced by determining nutrients and nutrient amounts to be added to the by-product to achieve the targeted nutritional values, including bypass protein and amino acid levels, of the nutritionally enhanced distillers, brewer or fermenter grain by-product after processing. The determined amounts of nutrients are mixed with wet distillers, brewers or fermenters grains. The mixture of wet distillers, brewers or fermenters grains and nutrients is dried at a dryer temperature or temperatures between from about 200°F to about 1,000°F until the moisture level in the mixture is between from about 0% to about 14%, the mixture is in a temperature range of from about 180°F to about 250°F, and the heat has increased the bypass protein level of the mixture to be within the desired ruminant animal bypass protein range.

[0025] The systems according to this invention produce an improved distillers, brewers or fermenters grain by-product by establishing desired nutritional values for the product to be produced, including a desired ruminant animal bypass protein range and amino acid levels. The enhanced product is produced by determining nutrients and nutrient amounts to be added to the by-product to achieve the targeted nutritional values, including bypass protein and amino acid levels, of the nutritionally enhanced distillers, brewer or fermenter grain by-product after processing. According to the systems and methods of this invention, the determined amounts of nutrients are mixed with wet distillers, brewers or fermenters grains. According to the systems and methods of this invention, the mixture of wet distillers, brewers or fermenters grains and nutrients is dried at a dryer temperature or temperatures between from about 200°F to about 1000°F until the moisture level in the mixture is between from about 0% to about 14%, the mixture is in a temperature range of from about 180°F to about 250°F, and the heat has increased the bypass protein level of the mixture to be within the desired ruminant animal bypass protein range.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Fig. 1 is a highly schematic diagram of one exemplary embodiment of a system according to the invention.

[0027] Figs. 2 and 3 display a flowchart of one exemplary embodiment of a method according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0028] Fig. 1 shows one exemplary embodiment of a system of this invention, which includes typical fermentation/ distillation processing equipment, such as, for example, one or more fermentation apparatus(es) (100)one or more distillation apparatus(es)(200), mixer(s)(300), extruder(s) (400), centrifuge(s) (500), dryer(s) (600), cooler(s), including air coolers, (700), packaging or containerizing apparatus (800), and temperature control device(s) that may optionally be applied to any or all of the aforementioned devices 100 through 800. These devices are connected via suitable means, such as, for example, electrical, electronic, mechanical and electro-mechanical devices and/or system. It should be understood that the systems, methods and resultant products according to this invention can use existing fermentation and distillation byproduct generation facilities and equipment, and/or new facilities and equipment. Moreover, one or more or all of the elements of the system may be controlled manually and/or by suitable electronic processing control equipment and/or software including, for example, controller 900. Controller 900 may employ hardware and/or software control elements. Elements 100 through 900 may be interconnected via interconnection means and/or bus 1000.

[0029] Fig. 2 shows one exemplary embodiment of the methods according to this invention for producing a nutritionally enhanced fermentation byproduct to achieve a nutritionally enhanced feed and/or feed supplement. The method commences in step S1000. Control then proceeds to step S1010, where desired nutritional values for an end product such as, for example, a mixture of wet distiller's, brewers or fermenters grain byproducts and nutrients are selected or determined. The desired nutritional values can be obtained, for example, from published data or, for example, determined on a case-by-case basis based on an analysis of nutrient deficiencies in animals to which the feed and/or feed supplement is to be fed or, for example from product specifications supplied by a customer. In one exemplary embodiment of the methods according to this invention, for simplicity, only two ingredients, e.g., wet corn distillers grains with solubles and 48% soybean meal, are used. In this exemplary embodiment of the systems and methods according to the invention, the nutrient formulas for two products of differing protein contents are established and the ingredients are

processed after being mixed in the wet stage. Table 1 shows nutrient values for a high quality corn distillers grain with solubles. This particular product has a crude protein (CP) value of 30.3% on a dry matter (DM) basis and an undegradable protein (RUP/UIP) value of 45.6% of the crude protein (CP). It has a lysine level of 2.13% and methionine value of 2.07% expressed as a % of the undegradable protein (RUP/UIP). These values, particularly protein, will vary between distillery sources and will also vary, even more so, when other grains such as barley or wheat are used in the distillation process.

[0030] The second ingredient in Table 1 is high protein soybean meal. This feedstuff is widely available to the animal agricultural industry as a dry product with about 8 to 12% moisture content. The values for crude protein, RUP/ UIP and methionine and lysine are typical values used by the animal agricultural industry. The soybean meal has a high protein level, 54% of DM, but has a low RUP/UIP of only 31.4% of the protein. It also has a relatively poor amino acid profile with a deficiency of methionine as compared to lysine.

Table 1: Values of Raw Materials

Ingredient	%DM	%CP of DM	%UIP of CP	%Methionine of UIP	%Lysine of UIP	%UIP Methionine of DM	%UIP Lysine of DM
Corn Dist Grains w/sol Wet	33.0	30.3	45.6	2.07	2.13	0.286	0.294
High Protein Soybean Meal	88.0	54.0	31.4	0.83	6.08	0.141	1.031

[0031] One may obtain a complete nutrient analysis of ingredients to be used in the formulation. If precise and repeatable results in the final product are not a high priority, standard values, such as those found in the National Research Council (NRC) reference, i.e., "Nutrient Requirements of Dairy Cattle, Seventh Revised Edition, published by the Committee on Animal Nutrition, National Research Council, 381 pages, 2001, may be used.

[0032] Next, control proceeds to step S1020, where an end product target nutritional formulation is developed using existing computer programs and nutritional values for distiller's wet by products and other ingredients.

[0033] The methods according to this invention allow the user to accurately produce a highly sophisticated protein supplement for ruminant animals. Selection of the types of ingredients, ratios of the ingredients and control of the processing allows the user to accurately predict and manipulate the following nutrient parameters for the end product:

1. The amount of rumen degradable protein in the wet mixture that will be converted to bypass protein (RUP/UIP) during processing.

2. Levels of both rumen degradable and rumen undegradable protein in the end product.

3. Levels of amino acids in the rumen undegradable protein and rumen degradable protein of the end product.

4. Ratios of amino acids in the rumen undegradable protein (RUP/UIP) in the end product.

5. Ratios of amino acids in the rumen degradable protein of the end product.

6. Post rumen digestibility of the rumen undegradable protein (RUP/UIP).

7. Fat levels in the end product.

8. Fiber levels in the end product.

9. Mineral levels in the end product.

10. Vitamin levels in the end product.

11. pH of the end product.

12. Moisture levels of the end product.

[0034] The systems and methods of this invention permit adjustment of absolute values of nutrient parameters 1 through 6 in a predictable manner. Absolute values of nutrient parameters 7-11 may be adjusted using conventional systems and methods, usually at the wet end of the feed formulation process, and nutrient parameter 12, i.e., product moisture levels may be adjusted using conventional systems and methods, usually downstream of the wet end of the feed formulation process. The systems and methods of this invention also permit predictable adjustment of values of nutrient parameters 1-6 relative to each other and relative to nutrient parameters 7-12.

[0035] According to the methods of the invention, the desired nutrient target(s) for the end product are selected on a finished dry product basis, i.e. a product with about 0-about 14% moisture. This can be done in consultation with customers and nutritionists to identify the needs of the target animals in a supplement and/or needed for a complete feed. There are very sophisticated nutritional models, such as, for example, the CPM-Dairy program, which is a well known dairy ration evaluation and formulation computer program, and excellent reference materials, such as the aforementioned NRC publication, known and available to those skilled in the art to facilitate the determination of nutrient specifications.

[0036] For this exemplary embodiment, the following table, Table 2, provides the target nutrient specifications for the two products that will be produced.

Table 2: End Product Nutrient Targets

Product	%DM	%CP of DM	%UIP of CP	%Methionine of UIP	%Lysine of UIP	%UIP Methionine of DM	%UIP Lysine of DM
40% Protein	88.0	45.45	75.0	1.60	4.8	0.545	1. 636
38% Protein	88.0	43.18	75.0	1.70	4.5	0.551	1.457

[0037] Referring again to Fig. 2, control then moves to step S1020 where a (wet basis) formula is determined to deliver the desired end results, i.e., a product with the desired nutritional values. With knowledge of the composition of the wet material, i.e. brewers, fermenters or distillers wet grains, a formula is determined to deliver the desired nutrients when the product has been processed. One method of formula determination involves converting the wet spent grain data to a dry matter basis and then proportioning it with similar dry matter data on the other ingredients in the mixture. This results in a formulation on a dry matter basis, which may be converted to wet weights for the purpose of weighing and mixing.

[0038] The following two tables (Tables 3 and 4) provide wet basis formulas to produce 2000 pounds (1 ton) of a finished product on a dry matter basis.

Table 3: Formula-40% Protein Product

Ingredient	Dry Matter Weight LBS	Wet weight LBS
Corn Dist Grains w/sol Wet	721.5	2186.4
High Protein Soybean Meal	1278.5	1452.8

Table 4: Formula-38% Protein Product

Ingredient	Dry Matter Weight LBS	Wet weight LBS
Corn Dist Grains w/sol Wet	913.1	2767.0
High Protein Soybean Meal	1086.9	1235.1

[0039] Use of the above formulas will result in the following nutritional values (Table 5), based on their wet analysis.

Table 5: Calculated Analysis Before Processing

Product	%DM	%CP of DM	%UIP of CP	%Methionine of UIP	%Lysine of UIP	%UIP Methionine of DM	%UIP Lysine of DM
40% Protein	55.0	45.45	34.82	1.220	4.834	0.193	0.765
38% Protein	50.0	43.18	35.95	1.334	4.475	0.207	0.695

[0040] Comparison of Tables 2 and 5 reveals significant differences in the target nutrient values set forth in Table 2 and the actual nutritional values obtained simply by mixing the feeds. These differences are provided to the final feed or feed supplement product according to the systems and methods of the invention.

[0041] Control then proceeds to step S1030 where a decision is made whether to premix the wet distillers grains and the nutrient sources in an existing wet distiller's grains production line, or to mix them offline, such as, for example, in an off-line mixer. If it is decided to premix the ingredients offline, the control moves to step S1040, where the ingredients are premixed with the wet distiller's grains. If it is decided to mix the ingredients with wet distillers grains online, then control proceeds to step S1050. In any event, the (wet) materials are mixed according to the aforementioned formula.

[0042] In various exemplary embodiments of the invention, the mixing can be done either in a separate batch mixer, or the materials which are added to the wet corn distillers grains can be injected into the wet corn distillers grains transport system (belt or auger) just prior to the dryer. In this exemplary embodiment, a batch mixer was used.

[0043] Using a batch mixer, the ingredients were weighed using calibrated scales and placed in a mixer. In various embodiments of the systems and methods according to the invention, one may use for example, a double ribbon mixer, a paddle mixer, a rotary mixer, etc. With the addition of the last material in the formulation, the mixer is set to operate for a predetermined time. The time necessary for the mixing should be determined using known scientific principles to identify the lowest coefficient of variation for that mix in the particular mixer.

[0044] Control then proceeds to step S1060 where a determination is made whether to extrude the mixture. If so, control proceeds to step S1070, and the mixture is extruded, with or without heat added thereto, and continues from there to step S1080. The mixture may be extruded either before the dryer or after partially removing the moisture in the dryer. If an extruder is used either before or after the drier care should be taken not to apply excess heat to alter the temperature of the mixture, such as, for example, to raise the temperature of the resultant product mixture to above about 250°F, which normally reduces the post ruminal digestibility of the RUP/UIP protein. If not, control proceeds directly to a dryer in step S1080 to feed the extruded mixture into the dryer and continues after drying to step S1090. In various exemplary embodiments of the invention, the dryer may have many different configurations depending, for example, on the size and scale of the processing operation. Processing temperatures will vary depending on a number of factors, including the

efficiency of the equipment, but typically are in the range of from about 200°F to about 1000°F. It should be noted that the processing temperatures may be above 250°C, to achieve a resultant end product temperature far below that, such as, for example, between about 180°C and about 250°C. The product exposure time in the dryer will also depend on the efficiency of applying the heat to the product.

[0045] The processing temperature used and the time of exposure will result in a final mixture temperature which will dictate the degree of conversion of rumen degradable protein to rumen undegradable protein (RUP/UIP) and the post rumen digestibility of the rumen undegradable protein. In general the higher the processing temperature and the longer the processing time the higher the resulting temperature of the mixture and the more rumen undegradable protein (RUP/UIP) produced. However, the temperature of the mixture should not exceed, in general, about 250°F to avoid_lowering the post ruminal digestibility of the RUP/UIP to an undesirable level. Results of testing at higher end product temperatures show reductions in pepsin digestibility of 20% or more when end product temperatures exceeds 230° F. Some reduction in pepsin digestibility may be acceptable based on the experience and professional judgment of the customer. Pepsin digestibility is an important characteristic of the end product and can be varied according to user demands. Acceptable final product temperatures have typically fallen within a temperature range of from about 180 °F to about 250° F.

[0046] The following two tables (Tables 6 and 7) provide a comparison of the nutrient values of the two example products before and after processing. Values are presented on a finished product (mixture) basis (12% moisture). Table 13 provides a comparison of all projected nutrient values and those nutrient values actually obtained. The final moisture level of the finished product normally will not exceed about 14% to prevent spoilage during shipment and storage.

Table 6: 40% Product

	%DM	%CP of DM	%UIP of CP	%Methionine of UIP	%Lysine of UIP	%UIP Methionine of DM	%UIP Lysine of DM
Before Processing	88.0	45.45	34.82	1.220	4.834	0.193	0.765
After Processing	88.0	45.45	**75.00**	**1.580**	**4.670**	**0.539**	**1.592**

[0047] The values of the product after processing in Table 6 and Table 7 were achieved at an end product temperature of about 218° F. The starting temperature was ambient temperature.

Table 7: 38% Product

	%DM	%CP of DM	%UIP of CP	%Meth of UIP	%Lys of UIP	%UIP Meth of DM	%UIP Lys of DM
Before Processing	88.0	43.18	35.95	1.334	4.475	0.207	0.695
After Processing	88.0	43.18	**75.00**	**1.720**	**4.521**	**0.557**	**1.464**

[0048] Analysis of Table 6 reveals that this exemplary embodiment of the systems and methods according to this invention resulted in a 115 percent increase of UIP (on a CP basis); a 30 percent increase of methionine (as a% of UIP) which then gives a 179 percent increase in UIP methionine (as a percentage of DM); and a 3.4 percent decrease of lysine (as a percentage of UIP) but an increase of 108 percent UIP lysine (as a percentage of DM). Analysis of Table 7 reveals that this exemplary embodiment of the systems and methods according to this invention resulted in a 108 percent increase of UIP (on a CP basis); a 29 percent increase of methionine (as a percentage of UIP) which then gives a 169 percent increase in UIP methionine (as a percentage of DM); and a 1.0 percent decrease of lysine (as a percentage of UIP) but an increase of 111 percent UIP lysine (as a percentage of DM).

[0049] Next, control proceeds to step S1100, where the mixture is cooled, for example, air cooled to a temperature of about 200°F or below, if needed. From step S1100 control proceeds to step S1110 where a determination is made whether to package the cooled product. If the product is to be cooled, such as, for example, by ambient or forced air, control then proceeds to step S1120 where the end product is packaged. Then control proceeds to step S1130, where it would have proceeded directly had the product not been determined to be packaged. In step S1130, the end product is shipped or transported to its final destination. Then the process ends in step S1140.

[0050] The aforementioned exemplary embodiments of the products according to the invention provide an indication of the increase in RUP/UIP protein and the amino acid levels and manipulation of the amino acid ratios in the RUP/UIP protein that is added to fermentation byproducts according to the systems, methods and resultant products of this invention. Other exemplary embodiments that have been obtained that demonstrate that the

resulting feed products, including feed supplements, made using the systems and methods of this invention achieve a predictable amount of bypass protein (RUP/UIP) and amino acid content and amino acid ratios in the finished products.

[0051] In other exemplary embodiments of the systems and methods according to this invention starts with 10 percent high protein soybean meal and 90 percent wet distillers grains. The high protein soybean meal is then increased by an additional amount, such as, for example, 10 percent for each new formulation until the mixture has about 90 percent soybean meal and 10 percent wet distillers grains.

[0052] Other exemplary embodiments of the systems, methods and resultant products according to this invention repeats the aforementioned method may use, for example, canola meal in lieu of, or in addition to, soybean meal.

[0053] Other exemplary embodiments of the systems, methods and resultant products according to this invention may use mixtures of canola meal and high protein soybean meal and add a mixture, such as, for example 5% high protein soybean meal and 5% canola meal to 90% wet distillers grains, and continue to vary the relative amounts of protein mix and wet distillers grains, as above.

[0054] In another exemplary embodiment of the systems and methods according to the invention, nine batches of a formulation of 66.4% wet corn dist grains and 33.6% high protein soybean meal were mixed using mechanical equipment and then were dried in a rotary dryer. The dryer consisted of an open vessel that was controlled with a thermocouple to maintain exact temperatures. A temperature probe was inserted into the mixture and readings were monitored throughout the drying procedure.

[0055] The temperature of the mixture increased rapidly to a range of 208°F to 210°F and remained constant for the approximate 2 hours of drying regardless of the temperature of the vessel. A range of drying temperatures from 350°F to 500°F were used. At the conclusion of the drying, the temperature of the mixture would rapidly rise indicating that the moisture of the mixture was reduced and the mixture was removed from the heat source and cooled. The mixtures were allowed to reach different end temperatures and thus different end moisture levels.

[0056] Samples of the cooled product were analyzed. Results of the analyses are shown in Tables 8-16 One part of each sample was used for wet chemistry tests (shown in Table 16), including amino acid analysis, (shown in Table 15). Another part of each sample was inserted into the rumen of a fistulated dairy cow. A standard 16 hour RUP/UIP was

measured and the resulting RUP/UIP was then tested for pepsin digestibility and for amino acid content. These results are shown in Tables 14 and 15.

[0057] Regression analysis of the RUP/ UIP of the nine batches heated and dried according to the methods described above yielded the following results. The R Square value of the nutrient values of the nine batches indicates that 85.68% of the variation in UIP is the result of the end temperature of the mixture. This results in a calculated significance level of 0.0343%, which means that 99.97% of the time, this RUP/UIP increase will occur. In other words, these results are highly predictable and repeatable.

[0058] The results of a regression analysis as shown in Tables 8, 9, 10, 11 and 12 clearly indicate that the bypass protein (RUP/UIP) content, expressed as a percentage of the crude protein is controlled and changed in a predicable manner by the temperature of the end product. The higher the temperature, the higher the bypass protein (RUP/UIP). The duration of the temperature, or variations in applied temperature do not appear to significantly influence this relationship. In the pilot plant in which the results set forth above were obtained, the drying times were in excess of two hours and the product was held at a temperature near the boiling point of water for most of that time.

[0059] Based on results as shown in Table 8, it is evident that the bypass protein (RUP/UIP) of the nutritionally enhanced fermentation byproduct may be controlled based on the temperature of the end product, whether it is a complete feed or a feed supplement. A formula expressing this relationship is:

UIP (% of CP) = (End Temp x 0.819) -107.644, (R^2=85.68%) (1)

[0060] Using equation (1) one can calculate the RUP/UIP of a mixture. For example, i.e., if the end temperature is 220°F, then the RUP/UIP will be 0.819 times 220 minus 107.644, which equals 72.54% RUP/UIP.

[0061] The data shown in Table 9 also reveal that pepsin digestibility was less predictable based on the product end temperature, but reached significant levels. The data was analyzed as a linear regression, but it appears that the one sample that had the highest bypass protein (RUP/UIP) had a depressed pepsin digestibility, making the relationship between bypass protein (RUP/UIP) and pepsin digestibility quadratic. It was also apparent that too much heat (amount and/or duration) adversely affects the pepsin digestibility of the end product. End temperature can range from 211°F to 223°F for the production of acceptable product without undue losses in digestibility.

Regression Analysis of Experimental Mixtures

TABLE 8

REGRESSION OF UIP % OF CP AND END TEMPERATURES

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9256589
R Square	0.856844399
Adjusted R Square	0.836393598
Standard Error	3.338503243
Observations	9

End Temp	UIP% CP Average
195	53.68
218	74.50
229	82.93
208	65.87
218	67.48
209	62.07
214	65.32
208	63.31
214	62.75

ANOVA

	df	SS	MS	F	Significance F
Regression	1	466.9767529	466.9767529	41.89784214	0.000342787
Residual	7	78.01922732	11.1456039		
Total	8	544.9959802			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-107.644092	26.91669969	-3.9991564	0.00519549	-171.2919273	-43.9962566	-171.2919273	-43.99625659
X Variable 1	0.818980743	0.126525442	6.47285425	0.000342787	0.519795829	1.118165656	0.519795829	1.118165656

TABLE 9

REGRESSION OF PEPSIN DIG. AND END TEMPERATURES

End Temp	0.0002% Pepsin Dig
195	79.52
218	63.11
229	43.13
208	54.02
218	59.63
209	64.19
214	63.11
208	62.31
214	67.67

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.801941608
R Square	0.643110343
Adjusted R Square	0.592126107
Standard Error	6.272275244
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	496.2491651	496.2491651	12.6139055	0.009323658
Residual	7	275.3900571	39.34143673		
Total	8	771.6392222			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	241.3064906	50.57025165	4.771708321	0.002031694	121.7269327	360.8860485	121.7269327	360.8860485
X Variable 1	-0.8442595	0.237712034	-3.55160604	0.009323658	-1.406358733	-0.28216026	-1.406358733	-0.282160258

[0062] Another statistically significant result of these examples is that the bypass protein (RUP/UIP) content is inversely related to the moisture content of the end product (Table 12). This relationship is described by the regression equation:

[0063] UIP (% of CP) = 87.536 – (1.133 x Moisture), (R^2=95.58%). (2)

[0064] This equation also calculates the RUP/UIP of a mixture, but based on its end moisture content after drying. Accordingly, the RUP/UIP for a product with an end moisture of 11% will be 1.133 times 11 subtracted from 87.536, which equals 75.07% RUP/UIP.

[0065] This appears to be due to the fact that the dryer moisture content increased when the end product was allowed to reach a temperature above the boiling point of water. These experiments were done at ambient atmospheric pressure. The aforementioned data indicate that there is an ideal temperature and moisture point range which includes about 218°F and about 12% water moisture content.

[0066] Moreover, experiments indicate that the drying temperature, measured, for example, by the temperature of the vessel in which the heating took place, apparently only affects pepsin digestibility, and the relationship between the temperature and the pepsin digestibility is relatively weak (Table 11). The one value for the lowest heating (350°F) caused the relationship to approach significance but all other values within normal range are basically random.

[0067] A regression analysis of UIP % of CP and vessel temperatures (Table 10) for the nine batches reveals that the R Square value is close to zero and, thus, there does not appear to be a predictable relationship between the vessel temperature (drying temperature) and the UIP content.

REGRESSION OF UIP % OF CP AND VESSEL TEMPERATURES Table 10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.331847778
R Square	0.110122948
Adjusted R Square	-0.01700235
Standard Error	8.323627442
Observations	9

Vessel Temp	UIP% CP Average
350	53.68
450	74.50
450	82.93
500	65.87
500	67.48
475	62.07
475	65.32
475	63.31
475	62.75

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	60.01656372	60.01656372	0.866255209	0.382970754
Residual	7	484.9794165	69.28277379		
Total	8	544.9959802			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	38.53081921	30.10892693	1.279714129	0.241424449	-32.66542866	109.7270671	-32.66542866	109.727067 1
X Variable 1	0.060514689	0.06501864	0.930728322	0.382970754	-0.093229853	0.214259231	-0.093229853	0.21425923 1

REGRESSION OF PEPSIN DIGESTIBILITY AND VESSEL TEMPERATURE Table 11

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.56885562
R Square	0.323596717
Adjusted R Square	0.226967676
Standard Error	8.634972937
Observations	9

0.0002%

Vessel Temp	Pepsin Dig
350	79.52
450	63.11
450	43.13
500	54.02
500	59.63
475	64.19
475	63.11
475	62.31
475	67.67

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	249.6999188	249.6999188	3.348855739	0.109947303
Residual	7	521.9393034	74.56275763		
Total	8	771.6392222			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	118.7711864	31.2351521	3.802484651	0.006693083	44.91184111	192.6305318	44.91184111	192.6305318
X Variable 1	-0.1234339	0.067450663	-1.82998791	0.109947303	-0.282929259	0.036061462	-0.282929259	0.036061462

[0068] A regression analysis of pepsin digestibility and vessel temperature for the nine batches reveals that the R Square value is a little higher, but a long way from indicating a significant relationship between the vessel temperature and the pepsin digestibility. However, the P value shows that the relationship is approaching significance and is close to 10%.

[0069] A regression analysis of UIP % of CP and final moisture (Table 12) for the nine batches reveals the highest correlation that we have in the data set with the R Square showing that 95.58% of the variation in UIP content is related to the moisture of the end product. What this means in practical terms is that the increase in RUP/UIP can be achieved by drying the mixed product to a final moisture content of about 8 to 12%, provided the end product reaches the desirable temperature of 211 to 223oF.

[0070] However, the relationship of end moisture level to RUP/UIP appears to be an anomaly because in subsequent research moisture levels approaching 0% were measured in relation to achieving the desirable RUP/UIP.

[0071] The regression analysis statistics for the nine batches are set forth in the product mixture Tables 8,9,10,11, and 12.

REGRESSION OF UIP % OF CP AND FINAL MOISTURE Table 12

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97763147
R Square	0.955763291
Adjusted R Square	0.949443761
Standard Error	1.855833613
Observations	9

H2O	UIP% CP Average
29.30	53.68
12.30	74.50
4.20	82.93
19.20	65.87
19.00	67.48
24.50	62.07
19.90	65.32
18.00	63.31
21.20	62.75

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	520.8871514	520.8871514	151.2396181	5.39244E-06
Residual	7	24.1088288	3.4441184		
Total	8	544.9959802			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	87.53634296	1.823964222	47.99235747	4.46139E-10	83.22335602	91.84932991	83.22335602	91.84932991
X Variable 1	-1.13313695	0.092140299	-12.2979518	5.39244E-06	-1.351013983	-0.91525992	-1.351013983	-0.915259924

Experimental Results--average of 9 samples

Table 13

Mixture : Wet Corn Dist Grains 66.4%, High Protein Soybean Meal 33.6%

	Nutrient	Calculated Values for Mixture		
Nutrients, % of Sample	**Target**	**Wet**	**Dry**	**Actual**
Dry Matter	88.000	49.478	89.421	88.40
Neutral Detergent Fiber		8.919	18.506	16.23
Effective NDF		0.806	1.543	0.00
Crude Protein	40.000	22.700	40.558	38.66
CP Sol Protein		3.624	8.265	4.44
UIP	30.000	8.075	15.258	28.80
ADF Protein		1.780	3.003	2.42
Fat		3.133	5.805	5.45
Acid Det Fibre		5.714	9.838	10.14
Ash		2.896	4.453	4.33
NSC Starch		11.617	17.407	29.67
NDF Lignin		0.780	1.534	2.25
Sol Protein NPN		2.083	5.312	
NDF Insoluble Protein		3.248	3.899	5.21
UIP Amino Acids, % of Sample				
Methionine		0.148	0.199	0.46
Lysine		0.389	0.656	1.35
Arginine		0.451	0.778	1.70
Threonine		0.320	0.490	1.13
Leucine		0.879	1.119	2.83
Isoleucine		0.364	0.559	1.25
Valine		0.439	0.704	1.45
Histidine		0.200	0.309	0.73
Phenylalanine		0.438	0.636	1.51
Tryptophan		0.132	0.209	
Methionine, % of UIP	1.610	1.830	1.560	1.58
Lysine, % of UIP	4.700	4.810	5.150	4.67
Isoleucine, % of UIP		4.510	4.390	4.34
UIP % CP	75.000	35.570	37.620	74.50
Lysine to Methionine ratio		2.628	3.301	2.96
Total Amino Acids, % of Sample				
Methionine		0.342	0.670	0.57
Lysine		1.191	2.147	1.96
Arginine		1.430	2.616	2.31

Threonine	0.856	1.558	1.44
Leucine	1.981	3.476	3.54
Isoleucine	0.959	1.780	1.61
Valine	1.117	2.048	1.87
Histidine	0.613	1.087	1.02
Phenylalanine	1.772	3.262	1.88
Tryptophan	0.276	0.494	
<u>Minerals, % of Sample</u>			
Calcium	0.128	0.229	0.38
Phosphorus	0.372	0.665	0.69
Magesium	0.154	0.276	0.29
Potassium	0.911	1.628	1.35
Sulphur	0.254	0.455	0.46
Sodium	0.056	0.099	0.12
Chloride	0.051	0.090	0.17
<u>Trace Minerals, ppm</u>			
Iron	62.264	111.246	103.21
Zinc	28.586	51.073	48.99
Copper	5.717	10.215	18.12
Manganese	17.661	31.554	23.06

"In vivo" Data on Experimental Mixtures Table 14

	Production Run Analysis			Lab Analysis			16 hr bypass, % of CP					
Mixture	Vessel Temp	End Temp	End Moisture	Prot	H2O	Prot DM Basis	Cow "A"	Cow "B"	Cow "C"	UIP Average	0.0002% Pepsin Dig	Dig. UIP %of CP
1	350	195	33.8	31.57	29.30	44.65	55.76	55.85	49.44	53.68	79.52	42.69
2	450	218	12.1	38.38	12.30	43.76	75.57	73.62	74.32	74.50	63.11	47.02
3	450	229	5.3	42.46	4.20	44.32	86.20	80.84	81.76	82.93	43.13	35.77
4	500	208	na	35.17	19.20	43.53	71.84	68.74	57.03	65.87	54.02	35.58
5	500	218	18.4	32.94	19.00	40.67	69.28	69.50	63.66	67.48	59.63	40.24
6	475	209	20.1	31.51	24.50	41.74	61.32	57.93	66.96	62.07	64.19	39.84
7	475	214	17.8	34.37	19.90	42.91	69.15	62.42	64.39	65.32	63.11	41.22
8	475	208	18.3	36.38	18.00	44.37	66.30	58.51	65.11	63.31	62.31	39.45
9	475	214	na	35.50	21.20	45.05	61.06	62.95	64.23	62.75	67.67	42.46
Wet Corn Dist	air dry			24.87	22.70	32.17	44.08	43.81	48.86	45.58	26.01	11.86
48% Soy	Commercial			46.81	11.00	52.60	22.86	26.17	45.04	31.36	94.96	29.78
Dry Corn Dist	Commercial			30.54	7.00	32.84	49.62	53.81	50.83	51.42	24.87	12.79

Amino Acid Analysis - gm/100 gm of Protein Table 15

	Values after Drying Corn Dist and Soy		Wet Corn Dist	Hi-Pro Soy	Commercial Corn Dist Dried Gr
Amino Acids	**Total AA**	**UIP AA**	**UIP AA**	**UIP AA**	**UIP AA**
Methionine	1.43	1.59	2.07	1.70	2.23
Lysine	4.96	4.67	2.13	6.35	2.21
Arginine	5.75	5.92	3.34	6.87	3.53
Threonine	3.59	3.95	3.66	4.13	3.66
Leucine	8.79	9.85	14.75	8.68	13.99
Isoleucine	4.01	4.27	3.63	5.01	3.89
Valine	4.67	4.95	5.09	5.64	5.05
Histidine	2.54	2.54	2.15	2.66	2.34
Phenylalanine	4.68	5.23	5.65	5.30	5.59
Tryptophan			-	-	-
Cystine	1.64	1.60	1.88	1.82	2.01
Methionine + Cystine	3.07	3.19	3.96	3.52	4.24
Tyrosine	3.30	3.73	4.39	3.96	4.24
Serine	4.02	4.75	4.41	4.30	4.22
Aspartic Acid	9.00	10.01	6.16	11.50	6.35
Glutamic Acid	15.46	18.11	19.35	16.76	18.61
Proline	4.94	5.67	7.86	4.86	7.92
Glyccine	3.74	3.90	3.12	4.34	3.30
Alanine	4.76	5.25	7.97	4.67	7.64
Hydroxyproline	0.13	0.12	0.27	0.00	0.20
Hydroxylysine	0.00	0.00	0.00	0.00	0.00
Taurine	0.14	0.08	0.16	0.00	0.00
Lanthionine	0.02	0.07	0.13	0.06	0.13
Ornithine	0.09	0.25	0.05	0.05	0.08

Chemical Analysis of Experimental Mixtures

Table 16 Values as % of Dry Matter

	Experimental Mixture Average of 9	**Corn DDG Air Dried**	**Soy Meal**	**Corn DDG Commercial**
Moisture	20.04	22.3	12.5	9.2
Dry Matter	79.96	77.7	87.5	90.8
Crude Protein,% DM	42.98	29.6	53.6	33.2
Available Protein, % DM	40.29	25.5	52.1	27.1
Unavailable Protein, % DM	2.70	4	1.5	6.1
Neutral Det. Crude Protein, % DM	6.26	4.7	1	7.5
Adjusted Protein, % DM	42.98	28.5	53.6	30.4
Soluble Protein, % DM	5.21	3.3	10	6.1
Soluble Protein % of CP	12.13	11.3	18.6	18.4
TDN, % DM	84.87	91.5	84.6	92
Net Energy Lactation, Mcal/lb	0.90	1	0.89	1
Net Energy Maintenance, Mcal/lb	0.95	1.03	0.94	1.04
Net Energy Gain, Mcal/lb	0.65	0.72	0.64	0.72
Acid Detergent Fiber, % DM	11.52	21.1	3.9	21.1
Neutral Detergent Fiber, % DM	18.75	33.3	7.7	38
Crude Fat, % DM	6.13	14.7	1.1	13.4
Lignin, % DM	2.58	4	0.6	3.1
Lignin / NDF Ratio	13.80	12	7.9	8.2
Ash, % DM	4.94	4.3	5.9	2.5
Starch, % DM	3.80	8.5	2.9	6.4
Sugar, % DM	10.15	4.9	11.1	5.8
Enzymatic NSC, % DM	13.95	13.4	14	12.2
NFC, % DM	33.51	22.8	32.7	20.4
Calcium, % DM	0.44	0.09	0.68	0.03
Phosphorus, % DM	0.78	0.97	0.76	0.79
Magnesium, % DM	0.32	0.42	0.31	0.32
Potassium, % DM	1.51	1.08	2.03	0.81
Sulfur, % DM	0.53	0.47	0.42	0.72
Sodium, % DM	0.13	0.222	0.031	0.126
Iron, PPM	116.52	182	117	88
Manganese, PPM	26.00	19	34	13
Zinc, PPM	55.92	82	45	45
Copper, PPM	21.20	30	18	6
Chloride Ion, % DM	0.20	0.27	0.03	0.24

[0072] In another exemplary embodiment of the systems and methods according to the invention, a number of different formulations of wet corn dist grains, soybean meal and in 2 instances blood meal were mixed and subsequently dried (Table 17). Whereas in the previously mentioned nine-batch exemplary embodiment, exact temperatures of the drying process were measured, a purpose of the instant

exemplary embodiment was to test different formulations over a variety of simulated commercial situations.

[0073] In this instant exemplary embodiment, pure corn distillers grains and pure soybean meal were dried along with various mixtures of these two ingredients. The mixtures ranged from 48% wet corn dist grains– 52% soybean meal to 17% wet corn dist grains – 83% soybean meal.

[0074] Drying temperatures were tested from a low 257^{O}F to a high of 379^{O}F. As in experiment #1, the temperature at the end of the drying period tends to rise and these are noted in Table 17(temperatures are dryer temp and not product temp).

[0075] The results clearly demonstrate that the RUP/UIP of the formulas is increased more than two-fold due to the heat applied during drying. The data also show that application of higher temperatures will impart greater RUP/UIP percentages; but, the higher heat will also decrease the pepsin digestibility as indicated by both the measurements at 0.02% and 0.0002% pepsin.

[0076] The RUP/UIP of corn distillers grains was increased to maximum levels by the application of lower dryer temperatures as compared to soybean meal. Soybean meal dried at the highest temperatures doubled in RUP/UIP content, but did not achieve levels equal to those of the 83% soybean meal – 17% wet corn distillers grains formula. A Maillard reaction, which may account for the change in RUP/UIP, may involve a complexing of the protein with the carbohydrate during heating in the test material. In one treatment, sucrose was added to pure soybean meal with little effect. Simple sugars do not appear to be involved in this reaction, whereas, the complex polysaccharides of the corn distillers grains work very well. Maillard reactions are discussed extensively in the literature and derive from the seminal work by L. -C. Maillard, which appeared in Comptes Rendus Acad. Sci., Ser. 2, vol. 54, page 66 (1912).

[0077] Very high RUP/UIP values were achieved with all the formulations of wet corn distillers grains and soybean meal.

[0078] The systems, methods and resultant products of this invention do not need all of the processing to be performed by a distiller, brewer or fermenter. Instead, the fermentation byproducts can by transported, such as, for example, by a pipeline or truck, to another location for processing.

[0079] While this invention has been described in conjunction with the specific embodiments above, it is evident that many alternatives, combinations, modifications, and variations are apparent to those skilled in the art. Accordingly, the preferred embodiments of this invention, as set forth above are intended to be illustrative, and not limiting. Various changes can be made without departing from the spirit and scope of this invention.

Table 17

Experiment #2

Sample Description	pH	Protein % of DM	Dryer Temp at End (oF)	Average Dryer Temp (oF)	Heating Time (min)	Bypass Protein, % of CP UIP at Start	UIP at End	0.02% Pepsin Dig. at Start	at End	0.0002% Pepsin Dig. at Start
Corn Dist Grains - 100%		29.3	257	257	240	45.58	71.21	74.39	72.12	26.01
Corn Dist Grains - 100%		30.0	320	289	105	45.58	93.30	74.39	63.59	26.01
Soybean Meal - 100%		52.7	392	379	60	31.36	65.60	98.64	95.51	94.96
Soy ML + 0.5% Sucrose		53.5	392	379	60	31.36	67.48	98.64	92.52	94.96
Corn Dist 48%-Soy 52%		42.8	392	379	105	33.70	79.39	93.25	86.89	79.63
Corn Dist 38%-Soy 62%	5.3	46.2	392	330	105	33.03	76.88	94.70	87.94	83.77
Corn Dist 38%-Soy 62%		46.1	338	298	120	33.03	62.97	94.70	91.79	83.77
Corn Dist 38%-Soy 62%		46.5	320	289	105	33.03	64.28	94.70	92.12	83.77
Corn Dist 38%-Soy 62%		44.9	257	257	150	33.03	64.53	94.70	94.03	83.77
Corn Dist 38%-Soy 62%	4.9	44.1	392	322	105	33.03	68.43	94.70	86.89	83.77
Corn Dist 38%-Soy 62%	5.5	45.6	392	322	115	33.03	69.52	94.70	79.34	83.77
Dist Sol 40%-Soy 60%		48.7	392	330	60	27.44	66.98	98.47	90.14	94.63
Corn Dist 28%-Soy 72%		49.3	392	379	105	32.46	81.06	96.01	88.36	87.48
Corn Dist 17%-Soy 83%	6.0	52.4	392	379	90	31.97	76.65	97.15	90.06	90.72
Corn Dist 17%-Soy #2 83%		50.9	392	379	85	31.97	71.92	97.15	93.07	90.72
Corn Dist 17%-Soy 83%	4.0	50.0	392	379	80	31.97	66.88	97.15	92.58	90.72
Corn Dist 17%-Soy 83%	7.2	48.3	392	379	80	31.97	76.24	97.15	93.59	90.72
Corn Dist 62%-Soy 26%-Blood 12%		54.7	392	379	80	56.32	70.32	94.22	90.92	84.96
Corn Dist 43%-Soy 42%-Blood 15%		57.9	392	379	80	54.36	82.96	96.05	93.47	90.18